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OLIVE MILL WASTEWATER TREATMENT USING ELECTROCOAGULATION TECHNIQUE

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Abstract

The electrocoagulation energy consumption, specific electrocoagulation energy consumption removal efficiency of COD and removal efficiency of TSS from olive mill waste water were examined by using electrocoagulation cell. Iron and aluminium were used as a material of electrodes. The distance between electrodes were 1, 1.5, 2, 2.5 and 3 cm, the electrocoagulation time were 10, 20, 30 and 40 mint and retention time 30 mint. The electrocoagulation voltage was 20 V while the electrical current was changing from 0.8 to 4 A. The electrocoagulation energy consumption increasing with decreasing distance between electrodes and increasing electrocoagulation time for two types of electrodes. At 1cm distance between electrodes and 40 mint electrocoagulation time, electrocoagulation energy consuming was 17.8 kW.h.m^{-3} for Al electrodes and 16.8 kW.h.m^{-3} for Fe electrodes. There were substantial ($p<0.05$) variations in COD removal efficiency and electrode distance. The effectiveness of the elimination of COD was 26.3 and 27.3 % for Fe and Al electrodes at a gap of 1cm between electrodes and 40 mints electro-coagulation times. The specific energy consumption increases with increasing process time. For Al electrodes and distance between electrodes 1 cm, the specific electrical energy consumption were 0.64, 1.15, 1.46 and 1.57 kW.h.g^{-1} COD at process time 10, 20, 30 and 40 mint respectively. The removal efficiency of TSS increasing with decreasing distance between electrodes and increasing electrocoagulation time for two types of electrodes. At 1cm distance between electrodes and 40 mint electrocoagulation time, the removal efficiency of TSS were 47.6 and 42.9 % for Al and Fe electrodes respectively.

Key words*: *electrocoagulation technique, olive mill wastewater, electrodes, COD, TSS

INTRODUCTION

The nutritional and health advantages of olive food crops are recognized. The berries are frequently utilized for oil mining and are consumed in a processed form. A total of 2,87 million tons of table olive were produced globally in 2018 [2]. Virgin olive oil has a unique taste because they contain phenolic compounds derived from the hydrolysis of oleuropein [19].

Olive oil products usually utilize around 0.4–0.8 m^3 of water in the debitter stage per ton of green olives. In the same investigation in Greece have been reported that, olive handling plants generating 3,9–7,5 m^3 wastewater for each ton of green olives and 0,9–1,9 m^3 wastewater for each ton of black olives [18]. In regard to inorganic chemicals with environmental hazards which require appropriate clean up procedures, the discharge generated includes various organic combinations such as phenolic. Usually, because to high organic content, these wastewaters possess strong chemical oxygen requirements (COD); for instance, this quantity is 48.500 mg.L^{-1} for effluent in olive mills [3, 13].

In comparison to control sites, soil irrigated with olive mill effluent showed considerably higher organic material concentration lower bulk density, and comparatively greater overall porosity, although lower macro porosity. Solvent exchange amongst inter and intra soil aggregate water was hampered when the soil became more covered with complex organic compounds coming from olive mill waste water[15]. Irrigation with untreated olive mill wastewater killed the plants in a couple of days. Treated olive mill wastewater was found to be useful in irrigating tomato crops at economic level [21].

[14, 9] investigated the effective performance of electrocoagulation technique in the treatment of olive mill wastewater using aluminium electrodes. Electrocoagulation is one of the efficient electrochemical methods for the cleaning of several types of wastewaters. During Electrocoagulation, when a potential change is applied between an anode, such as Fe or Al and the cathode, ferrous or aluminium and hydroxyl ions are generated, respectively, at the anode and the cathode. In the Electrocoagulation process, electrochemically generated aluminium can remove most contaminants present in olive mill waste water via precipitation and adsorption. The aluminium type acts as a coagulant by joining with the pollutants to form large size groups and can then be taken away via settling and flotation [12, 10, 23, 7].

[20, 5] showed that the optimal total suspended solids (TSS) and chemical oxygen demand (COD) removal was found at the optimum experimental parameters for example electrical current, pH, and electrocoagulation time. After electrocoagulation, most organic composites still remained in effluent. [16] resulted that a significant effect of electrical current and electrocoagulation time on the removal efficiency of total phenolic compounds and chemical oxygen demand.

Electrocoagulation includes the generation of coagulants in situ via dissolving electrically moreover aluminium or iron ions from aluminium or iron electrodes, respectively. Metal ions are produced at the anode, and hydrogen is released from the cathode. Hydrogen will also help float flocculated particles out of water. Electrodes can be arranged in unipolar or dipole patterns. These materials can be plate-shaped aluminium or iron, or they can be packed in chips, such as steel turning and milling. [1, 6, 11].

Total organic carbon, chemical oxygen demand, color, turbidity, or the concentration of a particular species such as a metal ion are all used to evaluate electrocoagulation efficiency. The anode of the sacrifice dissolves and must be constantly changed. In addition, the development of an oxide layer on the cathode surface may lead to reduced processing efficiency. To decrease electricity consumption, high conductivity is required for waste water [24, 17]. The current density and EC duration of electrocoagulation are the two main factors for eliminating pollutants, and the ideal way to reduce the energy consuming is to substantially improve them [8, 22].

The objective of the present study is to evaluate the performance of electrocoagulation on the treatment of olive mill waste water by exploring the effects of various process parameters such as electrodes materials, electrical current, distance between electrodes and electrocoagulation time on COD and TSS removal. Also, estimated electrocoagulation energy consumption.

MATERIALS AND METHODS

The olive mill waste water was taken from a traditional oil mill in El-Salhia, Egypt during the season 2019-2020. No chemical substance additives were used through the production olive oil. The specifications of fresh olive mill waste water were recorded (Table 1). The experiments were carried out in Agricultural Engineering Department, Faculty of Agriculture, Kafrelsheikh University, Egypt.

Specification of electrocoagulation cell

A laboratory model electrocoagulation (Fig. 1) was used for experiment. The power supply voltage was ranged from 0 to 30 V and the electrical current variations was 0 – 6 A. Surrounding temperature was stable through the experiment around 22 C°. Electrocoagulation unit made of plexiglass with the dimension of 20 cm ×10 cm × 15 cm and equipped with 7 parallel electrodes (4 anode and 3 cathode). Electrodes made of aluminium (Al) and iron (Fe). The dimension of electrodes was 8 cm × 3 cm ×0.3 cm and the effective area of electrodes was 168 cm^2. The distance between electrodes variations 1 – 3 cm. The electrodes were connected to the power supply and fixed voltage at 20 V. Digital magnetic stirrer for mixing olive mill waste water (mixing speed 200 rpm). At the end of the run, the solution stayed for 30 mint as a retention time.

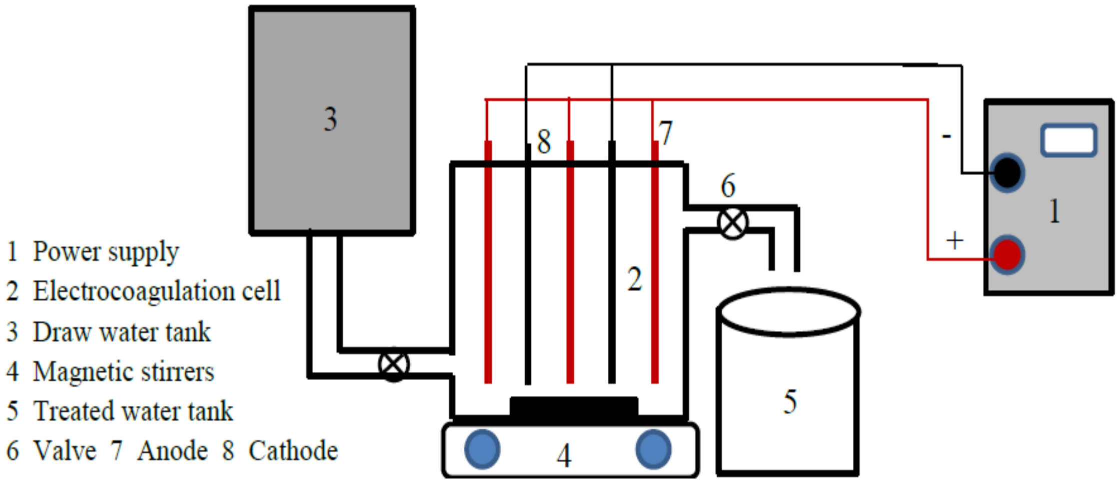

Fig. 1. The electrocoagulation cell model used in laboratory experiment
Source: Author's schematic drawing.

Measurements

Analysis of COD and TSS were determined by the procedure described in the standard method [4]. A digital calibrated pH meter was used to measure the pH of the Olive mill waste water. NO3, phenol, volatile acids and dray residue were estimated in food technology laboratory.

The electrocoagulation energy consumed, expressed as kW.h per m^3 of treated waste water. Removal efficiency of COD and specific electrocoagulation energy consumption kW.h per g of removed COD were calculated using following equations [16]:

$$Electrocoagulation\ energy\ consumption = \frac{V \times I \times t}{60 \times v}$$

$$Removable\ efficiency\ of\ COD\ (\%) = \frac{COD_{initial} - COD_{final}}{COD_{initial}} \times 100$$

$$Specific\ electrocoagulation\ energy\ consumption = \frac{Electrocoagulation\ energy\ consumption}{COD_{intial} - COD_{final}}$$

where: V is working electrical potential (in Volts), I is electrical current (A), t is electrocoagulation time (mint). *v* is the sample volume (litter), COD_{intial} is the initial concentration of the organic load ($g.L^{-1}$) and COD_{final} is final concentration of the organic load.

Experimental parameters

The voltage was constant at 20 V and the electrical current is measured in all treatments according to the resistance of the olive mill waste water. During the study the following treatments were tested:

1-Distance between electrodes: it included the five levels (1, 1.5, 2, 2.5 and 3 cm).

2-Electrocoagulation time: it included the four levels (10, 20, 30 and 40 mint).

3-Type of electrodes: it included tow types of electrodes (aluminum (Al) and iron (Fe)).

Statistical analysis

MATLAB statistical analysis software (Mathworks, USA) was used for carrying out the analysis of variance (ANOVA) and the least significance difference (LSD) tests at 95 % confidence level for obtained data.

RESULTS AND DISCUSSIONS

Effects of the experimental parameters on the olive mill wastewater, electrocoagulation energy consumption, COD removal efficiency and TSS removal efficiency were investigated in this section.

Olive mill wastewater specifications

Table 1 summarizes the specifications of olive matt wastewater before and after electrocoagulation under optimum conditions (distance between electrodes = 1cm and electrocoagulation time = 40 mint) for two types of electrodes (Fe and Al). As is clear from table 1, the changes of water quality after electrocoagulation for Al electrodes was better than Fe electrodes. COD removal efficiency were 27.29 and 26.33 % for Al and Fe electrodes respectively. Removal efficiency for TSS were 47.62 and 42.86 %

for Al and Fe electrodes respectively. All water specifications for Al electrodes were higher than Fe electrodes under all study parameters.

Table 1. Specifications of olive matt wastewater before and after electrocoagulation at distance between electrodes 1 cm and time 40 mint

Parameter	Olive matt waste water	After electrocoagulation		Removal efficiency, %	
		Al electrode	Fe electrode	Al	Fe
Temperature, °C	22	43 (±2)	42 (±2)		
TSS, mg. L^{-1}	2,100	1,100 (±20)	1,200 (±25)	47.62	42.86
pH	4.2	4.5 (±0.1)	4.5 (±0.1)		
COD, mg. L^{-1}	41,400	30,100 (±500)	30,500 (±400)	27.29	26.33
NO3, mg. L^{-1}	49	37 (±3)	38 (±2)	24.49	22.45
Volatile acids, mg. L^{-1}	9,000	6,700 (±100)	6,800 (±100)	25.56	24.44
Phenol, mg. L^{-1}	43.2	37.8 (±3)	38.1(±2)	12.50	11.81
Dry residue, mg. L^{-1}	15,460	12,900 (±600)	13,700 (±500)	16.56	11.38

Source: Own calculation.

Electrocoagulation energy consumption

The electrical current is important effective parameter in electrocoagulation systems. At Al electrodes, electrical current were 4, 2, 1.3, 1 and 0.8 A for distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively. Since electrocoagulation energy consumption is straight related to applied current and the voltage, electrocoagulation energy consumption of the electrochemical process at the time and steady state condition was stated increased at higher density. Distance between electrodes had a significant differences effect ($p<0.05$) on electrical energy consumption at different electrochemical process time and different electrode types. It can be seen from Fig. 2 the electrocoagulation energy consumption increasing with decreasing distance between electrodes for two types of electrodes. The electrocoagulation energy consumption for Al electrodes at distance between electrodes 1 cm were 4.4, 8.9, 13.3 and 17.8 kW.h.m^{-3} at time process 10, 20, 30 and 40 mint respectively. While, the electrocoagulation energy consumption for Fe electrodes at distance between electrodes 1 cm were 4.2, 8.4, 12.7 and 16.9 kW.h.m^{-3} at time process 10, 20, 30 and 40 mint respectively.

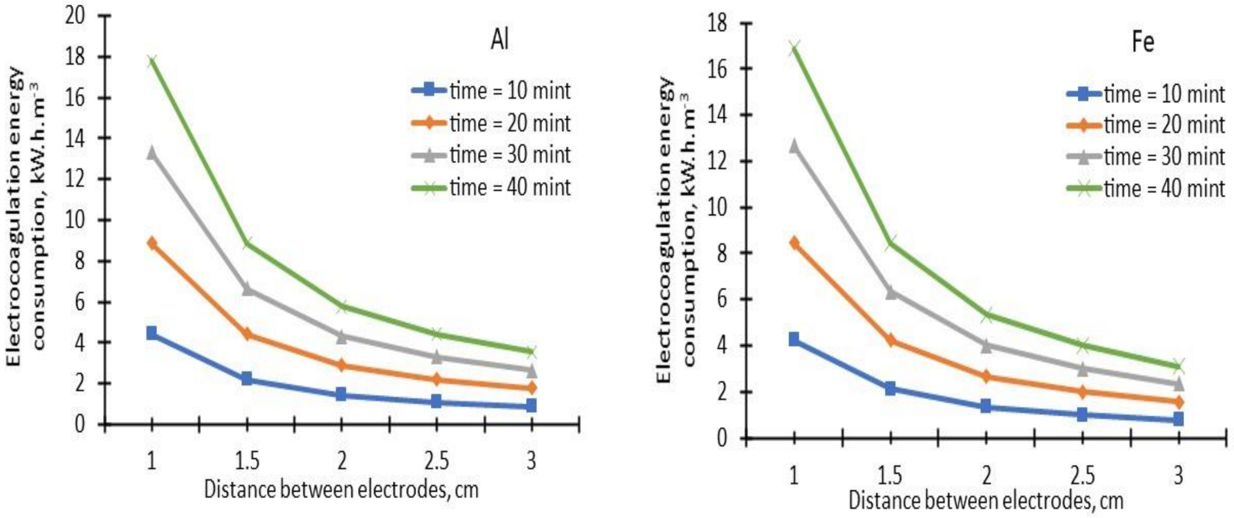

Fig. 2. Relation between electrocoagulation energy consumption and distance between electrodes (1, 1.5, 2, 2.5 and 3 cm) for two types of electrode at different process time (10, 20, 30 and 40 mint).
Source: Own calculation.

Electrocoagulation process time had a significant differences effect ($p<0.05$) on electrical energy consumption at different distance between electrodes and different electrode types. It can be seen from Fig. 3 the electrocoagulation energy consumption increasing with increasing process time for two types of electrodes. The electrocoagulation energy consumption for Al electrodes at time process 40 mint were 17.8, 8.9, 5.8, 4.4 and 3.6 kW.h.m^{-3} at distance between electrodes 1, 1.5, 2, 2.5 and 3cm respectively. While, the electrocoagulation energy consumption for Fe electrodes at time process 40 mint were 16.9, 8.4, 5.3, 4 and 3.1 kW.h.m^{-3} at distance between electrodes 1, 1.5, 2, 2.5 and 3cm respectively.

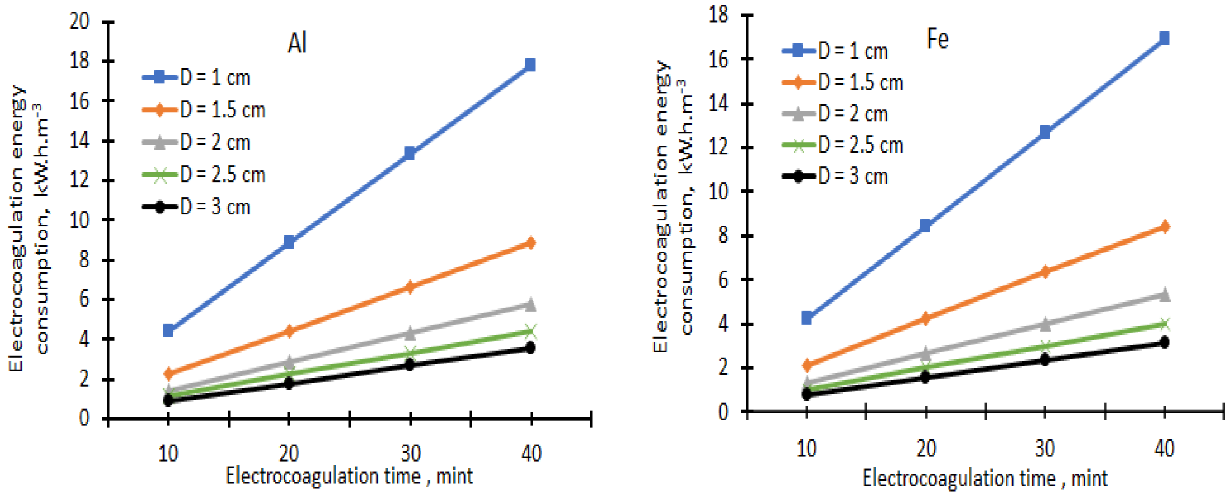

Fig. 3. Relation between electrocoagulation energy consumption and process time (10, 20, 30 and 40 mint) for two types of electrode at different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm).
Source: Own calculation.

The electrocoagulation energy consumption for Al electrodes were higher than the electrocoagulation energy consumption for Fe electrodes at all experiment conditions because the electrical conductivity for Al higher than Fe (Fig. 4).

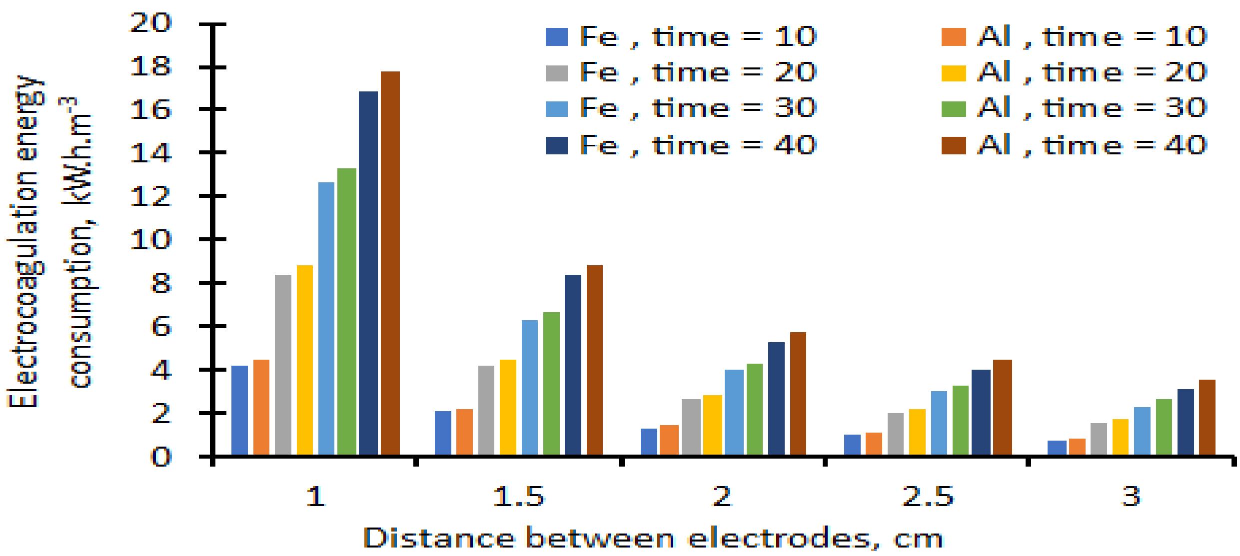

Fig. 4. Shows the compering electrocoagulation energy consumption for Al and Fe electrodes at different process time (10, 20, 30 and 30 mint) and different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm)
Source: Own calculation.

Removal efficiency of COD

The development of the removal COD concentration as a function of process time and distance between electrodes is significant for determining best conditions for the degradation of harmful organic substance. There were significant differences ($p<0.05$) between removal efficiency of COD and distance between electrodes. The removal efficiency of COD increasing with decreasing distance between electrodes for two types of electrodes. The removal efficiency of COD for Al electrodes at distance between electrodes 1 cm were 16.8, 18.6, 22.1and 27.3 % at time process 10, 20, 30 and 40 mint respectively. While, the removal efficiency of COD for Fe electrodes at distance between electrodes 1 cm were 16.4, 18.3, 21.8 and 26.3 % at time process 10, 20, 30 and 40 mint respectively (Fig. 5).

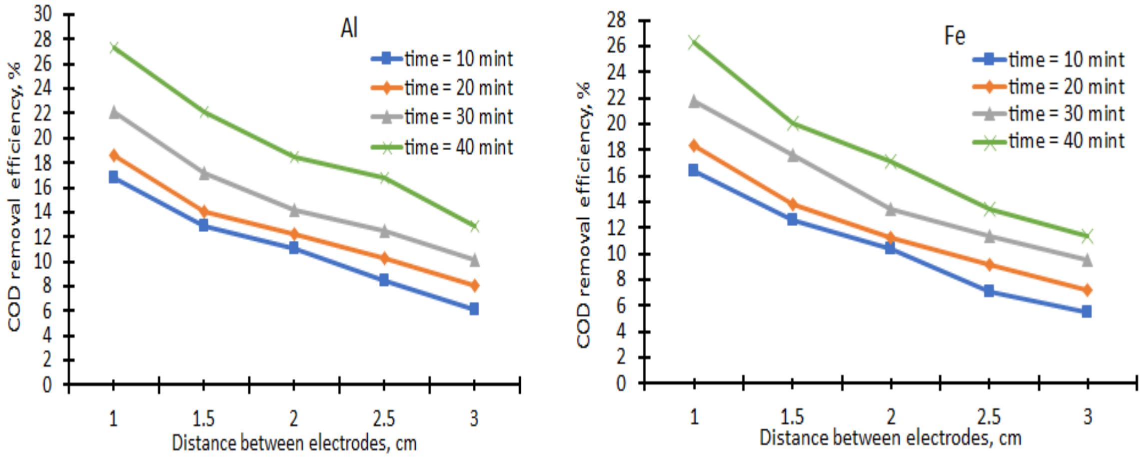

Fig. 5. Relation between removal efficiency of COD and distance between electrodes (1, 1.5, 2, 2.5 and 3 cm) for two types of electrode at different process time (10, 20, 30 and 40 mint)
Source: Own calculation.

There were significant differences ($p<0.05$) between removal efficiency of COD and process time. The removal efficiency of COD increasing with increasing process time for two types of electrodes. According to Fig. 6 the removal efficiency of COD for Al electrodes at process time 40 mint were 27.3, 22.1, 18.5, 16.8 and 12.9 % at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively. While, the removal efficiency of COD for Fe electrodes at process time 40 mint were 26.3, 20.1, 17.1, 13.5 and 11.4 % at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively.

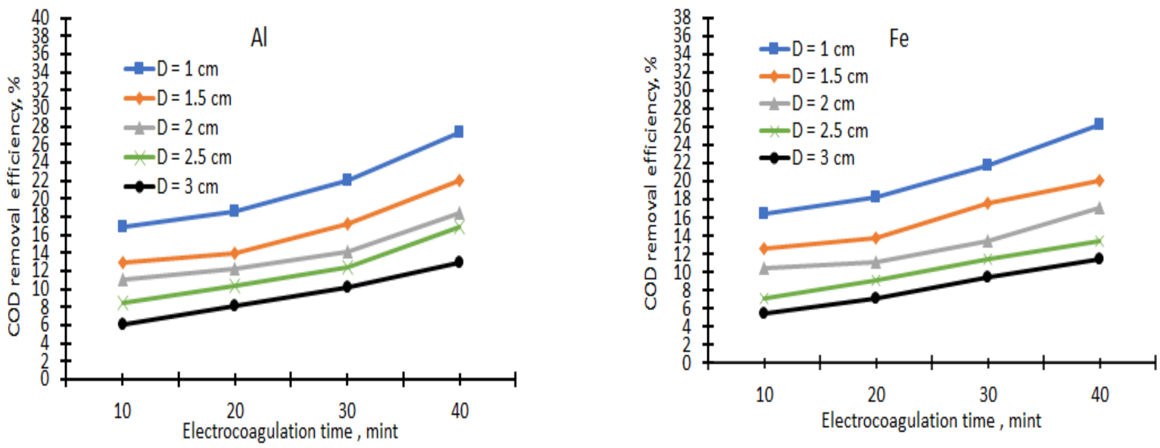

Fig. 6. Relation between removal efficiency of COD and process time (10, 20, 30 and 40 mint) for two types of electrode at different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm)
Source: Own calculation.

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There were significant differences ($p<0.05$) between removal efficiency of COD and types of electrodes (Al and Fe). Fig. 7 shows that the removal efficiency of COD for Al electrodes was higher than Fe electrodes for all experimental conditions. At process time 40 mint and distance between electrodes 1 cm the removal efficiency of COD were 27.3 and 26.3 for Al and Fe respectively.

Specific electrical energy consumption is one of important indicator for electrocoagulation process. As shown as from Table 2, the specific energy consumption increases with increasing process time. For Al electrodes and distance between electrodes 1 cm, the specific electrical energy consumption were 0.64, 1.15, 1.46 and 1.57 $kW.h.g^{-1}$ COD at process time 10, 20, 30 and 40 mint respectively. For Fe electrodes and distance between electrodes 1 cm, the specific electrical energy consumption were 0.62, 1.11, 1.40and 1.55 $kW.h.g^{-1}$ COD at process time 10, 20, 30 and 40 mint respectively. The specific energy consumption increases with decreasing distance between electrodes. For Al electrodes and process time 40 mint, the specific electrical energy consumption were 1.57, 0.97, 0.75, 0.64 and 0.67 $kW.h.g^{-1}$ COD at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively. For Fe electrodes and process time 40 mint, the specific electrical energy consumption were 1.55, 1.01, 0.75 0.72 and 0.66 $kW.h.g^{-1}$ COD at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively.

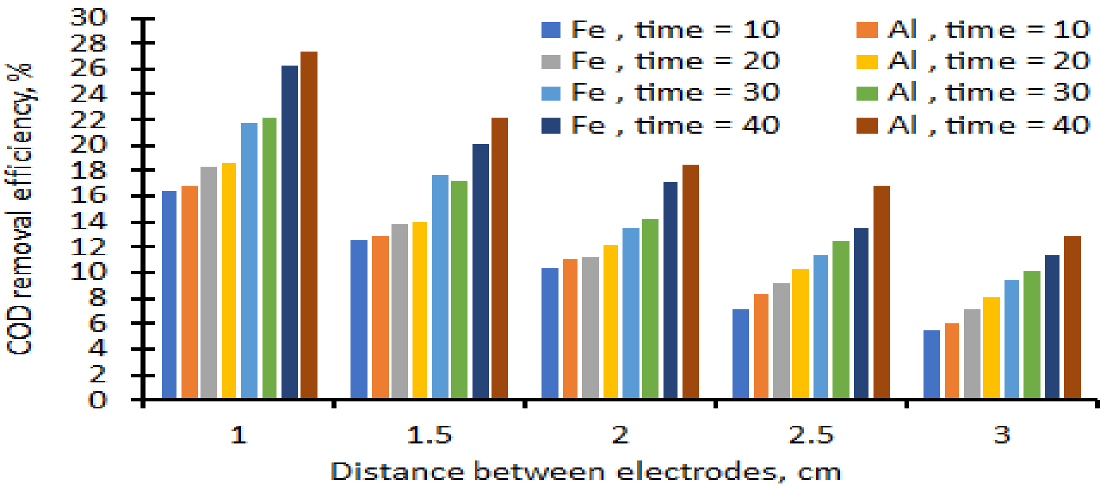

Fig. 7. Shows the compering removal efficiency of COD for Al and Fe electrodes at different process time (10, 20, 30 and 30 mint) and different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm).
Source: Own calculation.

Table 2: Specific electrical energy consumption (kW.h per g removal of COD) under different experimental conditions

Type of electrode	Time, mint	Specific electrical energy consumption, $kW.h.g^{-1}$ COD				
		Distance between electrodes, cm				
		1	1.5	2	2.5	3
Al	10	0.64	0.42	0.31	0.32	0.35
	20	1.15	0.77	0.57	0.52	0.53
	30	1.46	0.94	0.74	0.64	0.63
	40	1.57	0.97	0.75	0.64	0.67
Fe	10	0.62	0.40	0.31	0.34	0.34
	20	1.11	0.74	0.58	0.53	0.52
	30	1.40	0.87	0.72	0.64	0.59
	40	1.55	1.01	0.75	0.72	0.66

Source: Own calculation.

Removal efficiency of TSS:

There were significant differences ($p<0.05$) between removal efficiency of TSS and distance between electrodes. The removal efficiency of TSS increasing with decreasing distance between electrodes for two types of electrodes. The removal efficiency of TSS for Al electrodes at distance between electrodes 1 cm were 9.2, 18.4, 38.8 and 47.6 % at time process 10, 20, 30 and 40 mint respectively. While, the removal efficiency of TSS for Fe electrodes at distance between electrodes 1 cm were 7.3, 16.4, 33.1 and 42.9 % at time process 10, 20, 30 and 40 mint respectively (Fig. 8).

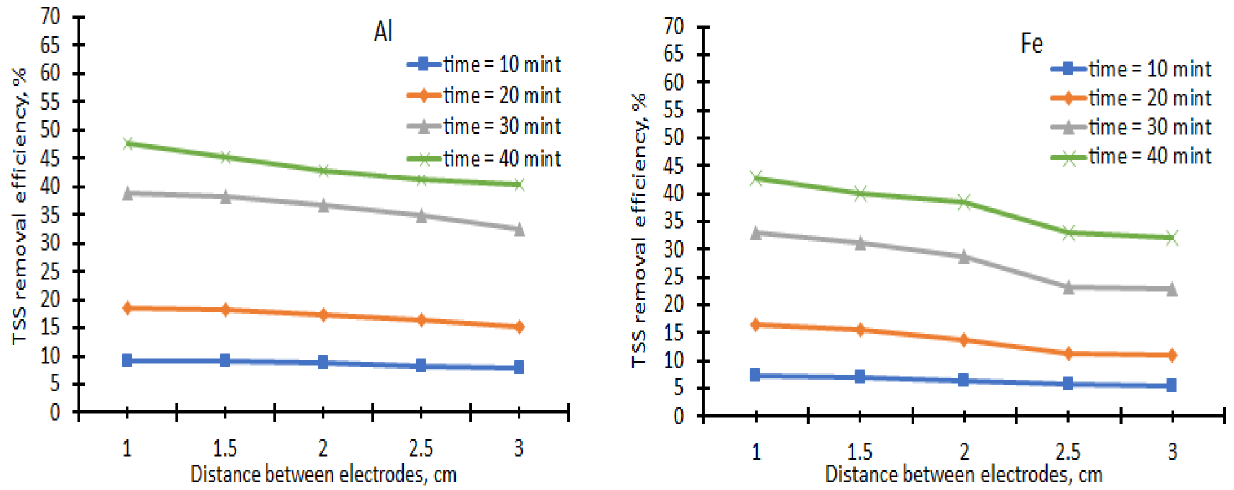

Fig. 8. Relation between removal efficiency of TSS and distance between electrodes (1, 1.5, 2, 2.5 and 3 cm) for two types of electrode at different process time (10, 20, 30 and 40 mint)
Source: Own calculation.

There were significant differences ($p<0.05$) between removal efficiency of TSS and process time. The removal efficiency of TSS increasing with increasing process time for two types of electrodes. According to Fig. 9, The removal efficiency of TSS for Al electrodes at process time 40 mint were 47.6, 45.2, 42.8, 41.2 and 40.4 % at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively. While, the removal efficiency of TSS for Fe electrodes at process time 40 mint were 42.9, 40.2, 38.4, 33.1 and 32.2 % at distance between electrodes 1, 1.5, 2, 2.5 and 3 cm respectively.

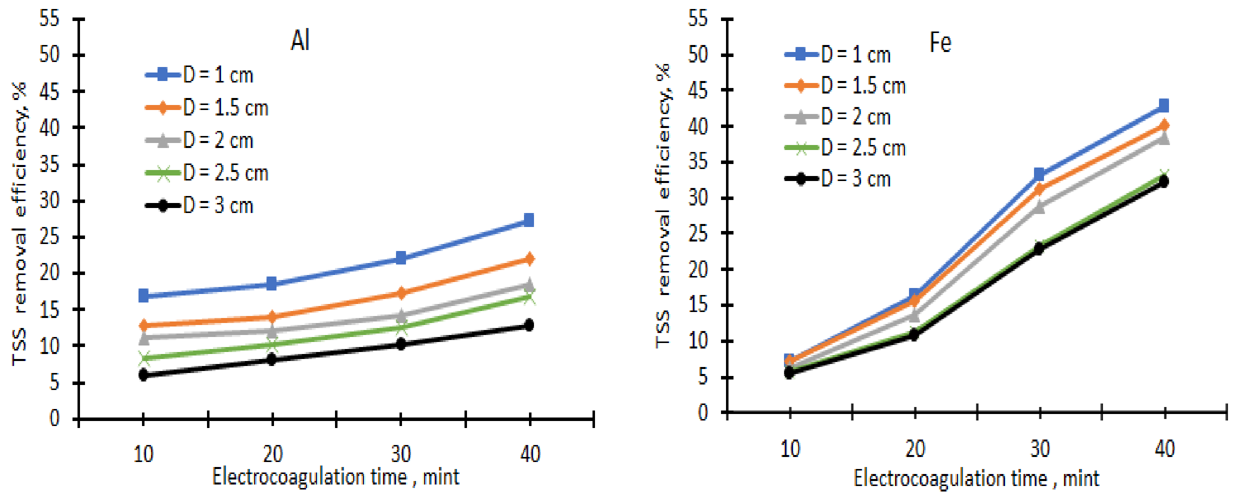

Fig. 9. Relation between removal efficiency of TSS and process time (10, 20, 30 and 40 mint) for two types of electrode at different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm)
Source: Own calculation.

There were significant differences ($p<0.05$) between removal efficiency of TSS and types of electrodes (Al and Fe). Fig. 10 shows that the removal efficiency of TSS for Al electrodes was higher than Fe electrodes for all experimental conditions. At process time 40 mint and distance between electrodes 1 cm the removal efficiency of TSS were 47.6 and 42.9 for Al and Fe respectively.

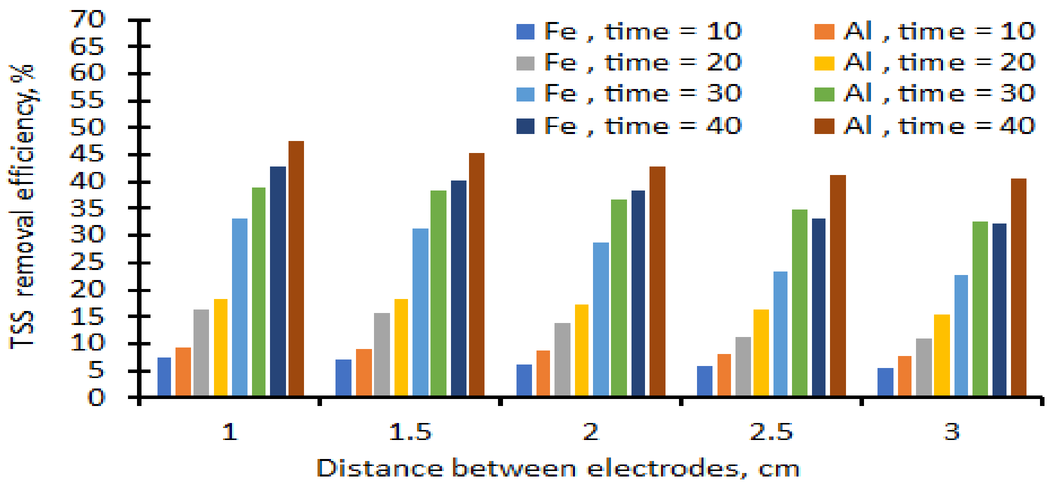

Fig. 10. Shows the compering removal efficiency of TSS for Al and Fe electrodes at different process time (10, 20, 30 and 30 mint) and different distance between electrodes (1, 1.5, 2, 2.5 and 3 cm)
Source: Own calculation.

CONCLUSIONS

Electrocoagulation one of the most electrochemical methods for waste water treatment. The electrocoagulation can be used to treat olive mill waste water. To obtain the optimum efficiency of electrocoagulation cell using Al electrodes, distance between electrodes 1 cm and electrocoagulation time 40 mint. In future studies, the olive mill wastewater treated in this process can be mixed with fresh water in different proportions and use in irrigation of agricultural crops and study the effect of that on soil structure and crop growth rate.

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